GeoJournal
https://doi.org/10.1007/s10708-018-9865-4

The value of crowdsourced street-level imagery: examining the shifting property regimes of OpenStreetCam and Mapillary

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Abstract OpenStreetCam and Mapillary are two increasingly popular online services centered on providing street-level imagery through close association with the OpenStreetMap platform and crowdmapping community. While both services provide crowdsourced street-level imagery, the differences in their aims and operations present an opportunity to discuss the various ways in which commercialization dynamics and crowdmapping practices are reshaping each other in the geoweb. This is significant because crowdmapping relies on massive distributed pools of unpaid labor, and is often characterized by a discourse and identity of community-centered sharing that eschews profit-seeking as a central motive. While the use of OpenStreetMap by commercial products is not new, the emergence of crowdsourced street-level imagery is an innovation with significant consequences. Projects like Mapillary and OpenStreetCam have the potential to both change the collaborative dynamics that drive OpenStreetMap, and simultaneously disrupt the state of street-level imagery ecosystem, which has been dominated by a single private provider: Google Street View. In light of this, crowdourced street-level imagery should be assessed, not only in technical terms, but through the full range of its political-economic ramifications. To this end, in this article we examine the role of commercialization in crowdmapped street-level imagery through a property regimes framework. Using this approach, we identify, analyze, and critique the allocation of rights, roles, and economic value within these services, thus shedding light on the emergence of crowdsourced street-level imagery in the context of the geoweb, and the digital and 'sharing' economies.

Keywords Crowdmapping · Street-level imagery · Geoweb · Mapillary · OpenStreetCam · OpenStreetMap · Google Street View · Property regimes

Introduction

This article sets out to analyze the creation and allocation of value in crowdsourced street-level imagery platforms through a property regimes framework. Street-level imagery consists of connected sequences of georeferenced images of real-world locations that can be explored and traversed online. In the past decade, thanks to the increase in computational resources and the growth of the geoweb, street-level imagery has gone from a novelty to a widely used virtual navigational and professional tool. In this time, Google Street View has become

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Published online: 07 March 2018

practically synonymous with street-level imagery due to its extensive coverage and popularity, as well as its integration with the suite of Google services, particularly Google Maps (Fisher 2013). This has meant that the value creation and allocation from street-level imagery has thus far been dictated by the proprietary models imposed by Google through the Street View product (and by less-influential corporate competitors with a similar model such as StreetSide by Bing Maps). However, this established model is on the verge of disruption through the emergence of new players that rely on the incorporation of crowdsourced image collection.

Mapillary and OpenStreetCam constitute a radical innovation in the collection of street-level imagery, since they are commercially-oriented services that rely on crowdsourcing for the provision of their content. Such an enterprise model not only eschews the considerable fixed costs of image collection infrastructure, such as Google's global vehicle network, but also leverages the volunteer labor of thousands of users into building a navigable virtual environment, with negligible collection costs. In order to achieve this critical mass of pooled human labor, both of these projects heavily rely on the user community that has grown around OpenStreetMap (OSM), a popular free and open crowdsourced geographic database operated by the not-for-profit OpenStreetMap Foundation. Through their intersections with OSM and its user community, the innovations in crowdsourced street-level imagery advanced by Mapillary and OpenStreetCam raise crucial questions about the monetization of volunteer labor in the geoweb and the role of crowdsourcing in articulating circuits of value creation in the digital economy.

To this end, in the present article we advance the framework of property regimes to analyze the circuits of value creation and allocation emerging in the environments of crowdsourced corporate street-level imagery. The property regimes framework was introduced by Schlager and Ostrom (1992) in response to a lack of analytical clarity in the conceptual grammar used to analyze property rights. This framework sought to address the ambiguity of terms such as "common-property resource", while providing a more nuanced alternative to monolithic theories of property that consider it a unitary right that is invariably fully 'owned' by actors such as individuals, the public, or the state. Schlager and Ostrom introduced a "conceptual schema for arraying property-rights regimes that distinguishes among diverse bundles of rights that may be held by the users of a resource system" (1992, p. 249). In recent contributions in the geoweb literature, the property regimes framework has been extended to account for the distribution of rights in geospatial data, and the technical and legal means used to allocate them to various actors (Alvarez León 2016; Alvarez León and Gleason 2017).

In this article we deploy the property regimes framework to analyze the creation and allocation of economic value through Mapillary and OpenStreetCam. Specifically, we identify the actors involved in the creation of economic value, the roles they play, and the mechanisms for the distribution and allocation of value. Furthermore, the property regimes framework allows us to track how property rights are allocated amongst various actors, as well as identify the set of rules governing this process. Through this analysis, we go beyond the rhetoric of collaboration that often characterizes crowdsourced networks, and show how the efforts of the crowd to collect street-level imagery are being leveraged in various ways for the creation of economic value.

In the next section we outline the main features of the political economy of crowdsourced street-level imagery. Section three covers the specific characteristics of the two leading platforms in this sphere: Mapillary and OpenStreetCam. In section four, we analyze the tensions between competition and cooperation arising due to the use of crowdsourcing for the creation of economic value. Following this, in section five, we develop a property regimes analysis of the creation and allocation of value through crowdsourcing Mapillary and OpenStreetCam. This framework allows us to trace the various actors involved in the creation of economic value through crowdsourced street-level imagery, and place this process in the broader context of the geoweb's ongoing neoliberal shift. Section six concludes the article by discussing the broader implications of the growth of crowdsourced street-level imagery platforms.

The political economy of crowdsourced street-level imagery

Street-level imagery platforms emerged in the mid-2000s out of an integration between mapping

platforms such as MapQuest and Google Maps, and images of urban landscapes, which were initially used as reference for real estate listings. The first movers in this technology were Amazon and Microsoft, with their products Block View and StreetSide, launched in 2005 and 2006, respectively. These products signaled a new stage in the provision of geographic information online through navigable virtual environments, while revealing the significant conceptual and technical challenges that this type of product would have to overcome. Amazon Block View was paired with the company's Yellow Pages service and provided a photography of each storefront; however, it never achieved extensive coverage, and the framing of a business directory was a limiting factor in the service. Microsoft StreetSide, on the other hand, provided an innovative interface that offered a view through the windshield of a car to simulate movement through space (Fisher 2013). However, this resulted impractical from a user perspective and lacked panoramic views. Microsoft's service was upgraded in 2011 with Street Slide, a new interface that allowed sliding panoramic navigation along streetfront landscapes, different from the 'bubble' 360-degree navigation featured in StreetSide (Lardinois 2011; Microsoft Research 2010). However, this panoramic navigation has since been discontinued, and Bing Maps StreetSide has yet to reach widespread adoption comparable to the market leading competitor, Google Street View.

The limitations of these two early platforms created a space for Google to improve on street-level imagery by tackling the technical challenges of imagery collection, coverage, and integration into seamlessly navigable environments. The product that resulted from this, Google Street View, was launched in 2007 and represented a qualitative leap that has become the standard street-level imagery platform, achieving exponential growth and global dominance of the market (Smith 2013). On the technical front, the differences of Google Street View can be attributed to innovations such as the R5 and R7 rosette cameras, allowing 360-degree panoramic, high-resolution image capture (Anguelov et al. 2010), the deployment of a Google vehicle network for continuously growing spatial coverage, and the integration with Google Maps into a user-friendly interface that allows users to easily toggle between the Google Search, Google Maps, and Google Street View (Vincent 2007).

As a geographic visualization tool, street-level imagery goes beyond the graphical abstractions of maps by assembling virtual and interactive photographic representations of space. The environments built through street-level imagery are navigable by the user, and therefore virtual in the sense that, by being georeferenced, they are anchored in real-world locations. This enables the user to have an immersive experience that reproduces on a device screen, core aspects of actual physical navigation, such as visual representations and movement simulations.

By incorporating immersiveness, verisimilitude, and immediacy of representation into navigable environments, street-level imagery has become a widely used navigation tool. Furthermore, as technology and automobile companies have bet through massive investments on the development of self-driving vehicles, they have come to perceive street-level imagery as an asset of extraordinary value that can serve as a key component for next-generation mapping and navigation systems (Hoffman, n.d.). Presently, Google Street View is the market leader in street-level imagery, and boasts the widest coverage and integration with Google's own search and mapping services. However, the recent emergence of two platforms, OpenStreetCam and Mapillary, has the potential to reshape this landscape through a new model built on the crowdsourced collection of imagery, particularly by leveraging the capabilities and user base of OSM, one of the world's largest collaborative online mapping projects. While both platforms are created to serve commercial ends, they have put forth messaging that signals their support of OSM.

This is one of the principal tensions with the model of crowdsourced street-level imagery advanced by OpenStreetCam and Mapillary: while the license agreements and flows of capital are evidence of these platforms' commercial orientation, their success depends on attracting unpaid contributors, which in turn relies on a message of collective collaboration and their interface with OSM and its community. Yet, in the process of creating economic value from volunteer labor, these platforms also lead to marked improvements in OSM quality, and their development teams have genuine close ties with the OSM community. Nevertheless, competition between the platforms and the continuous need to expand their coverage through contributions have led them to develop gamified

strategies to encourage participation, such as public leader boards, which are not present in OSM.

Thus, in addition to disrupting the street-level imagery collection model established by Google Street View, Mapillary and OpenStreetCam have the potential to create a rift in the OSM community. While this community has to date been largely focused on enhancing the scope and precision of OSM, the emergence of multiple platforms for crowdsourced street-level imagery compels contributors to make a choice that splits the community's effort. This has prompted debates and discomfort about the rise of commercially-driven competition, and some contributors are starting to consider what a truly open street-level imagery platform would look like.

The creation of value in the context of street-level imagery has thus far been defined by Google's centrality as the main player in this realm. The collection of images by Google vehicles and their integration into a navigable visual platform is automatically protected by the company's copyright, which gives Google control over how value creation from this good is allocated. On the other hand, the emergence of crowdsourced street-level imagery platforms, such as Mapillary and OpenStreetCam, articulates an alternative circuit of value production built on the use of volunteer labor. In this circuit, volunteers can own the images they contribute, but cannot appropriate the economic value produced by them. Conversely, the companies who own the imagery platforms do not own the user-contributed imagery, but can appropriate economic value, and retain control of its allocation through the development and implementation of technical and legal frameworks designed for this purpose. While these emerging circuits of value are organized around a commercial logic, they are significantly influenced by, depend on, and potentially impact upon, social dynamics that have shaped the development large-scale collaborative projects such as OSM.

The various ways that people create and use data in OSM, and crowdsourced volunteered geographic information (VGI) more broadly, have been scrutinized in the academic literature. The influence of place and the power of contributors to add place-specific knowledge is a key theme in these studies, and constitute a benefit of VGI over commercially produced map products (Elwood et al. 2013; Goodchild 2007; Sui and Goodchild 2011; Wilson and Graham 2013). At the same time, it is erroneous to believe that contributors to VGI-style projects are all private individuals mapping just their own personal geographies, or even groups of dedicated hobbyists collaborating on local projects.

In fact, a variety of actors both contribute to and derive different kinds of benefit from crowdsourced spatial data. Through qualitative interviews, Lin (2011) identified the involvement of four types of players in the OSM arena, namely businesses, governments, NGOs/Third Sector, and individuals (who may or may not be loosely organized). Caquard (2014) speaks of mapping in the social media era as reflecting "the interests of a heterogeneous coalition of technologically savvy individuals and private-sector companies". In evidence of this, some heavy OSM corporate users such as Mapbox and Telenav have hired employees to either improve the data directly or build tools to help others do so. These practices have been openly stated by representatives of such organizations (Barth 2015) and detected by data analysis tools (Quinn and MacEachren 2018). The impact of paid mappers on VGI coverage, quality, and applicability has not yet received deep critical examination, although the OSM Data Working Group is in the process of investigating the creation of a "Directed Editing Policy" for corporate contributors.[1]

The derivation of revenue from VGI is not unique to businesses that rely on OSM. Wikimapia is a similar project in which contributors also trace and describe geographic features, with all of the data available to the public through a Creative Commons license. At the same time, Wikimapia operates a privately owned venture that makes income from advertising. For example, businesses can pay to have their location indicated with a more distinctive and interactive icon (http://wikimapia.org/ads/) to stand out on the map. A further example of VGI harnessed for profit is Google's Waze app that uses individuals' smartphone locations to detect traffic patterns and make routing suggestions, while in the meantime offering location-based advertisements.

Examining the rise of new "corporate regimes of spatial data governance", Leszczynski (2012) has identified three emergent characteristics that comprise

[1] See the Wiki on OSM's Organized Editing Policy (accessed Sept. 25, 2017): http://wiki.openstreetmap.org/wiki/Directed_Editing_Policy.

part of a neoliberal shift: (1) free labor through crowdsourcing, (2) a tight grip on ownership of data and apps, and (3) a sense of unaccountability from consequences arising from the content. These elements are present in both Mapillary and OpenStreetCam, although to varying degrees. Both obtain their content from voluntary labor. The ownership piece is more nuanced, and to elucidate it we deploy the property regimes framework later in this paper. The (un)accountability is evident in the disclaimers, limitations of liability, and indemnification clauses in both the OpenStreetCam and Mapillary terms of use, attempting to release the parent companies from any harm caused by the images that constitute their products.

In light of these transformations, Elwood and Leszczynski (2011, 2012) have called for a more robust understanding of the political economy of the geoweb, a term that they define as the merging of geographic information with online content that has taken place, in large part, thanks to the aggregation of volunteered geographic information across myriad platforms, domains, and physical locations (Elwood and Leszczynski 2011, p. 6). As shown in the above examples, the use of volunteer labor for the production of online digital goods and services has become a prominent practice in the digital economy, along with reframed ownership schemes and an avoidance of accountability by data and imagery providers. In this context, by leveraging VGI for the construction of for-profit services, Mapillary and OpenStreetCam are representative of an ongoing neoliberal shift in the political economy of the geoweb that requires further investigation.

Crowdsourcing street-level imagery: Mapillary and OpenStreetCam

Mapillary is a company based in Malmö, Sweden that allows contributors to capture and upload street level images through a mobile phone app. The app takes a new photo at a set time interval based on whether the user is walking, biking, or driving. Location and orientation metadata from the phone's GNSS receiver and compass are attached to each image. Mapillary released its first app for iPhone in November 2013, which was followed in January 2014 with an Android app (Metz 2014). Mapillary's momentum as a company is evident through the approximately 150 million images it has collected, as well as the USD $8 million of Series A startup funding it received in 2016 from a variety of venture capital firms including Atomico and Sequoia (Solem 2016).

A central part of Mapillary's strategy is driven by an explicit attempt to differentiate its spatial coverage from that offered by existing services. For example, it encourages its contributors to map areas not easily accessed through Google Street View. This includes places designed for pedestrian traffic, such as trails, paths, and stairways. Mapillary also touts its coverage in places like Cuba where Google Maps has not yet collected Street View data (Whitefield 2016).

At the time of this writing, all images accessed through the Mapillary website or API are available under a Creative Commons Attribution-ShareAlike license (CC BY-SA), and individual contributors retain ownership of the photos they upload, including the ability to delete them. At the same time, "contributors grant Mapillary a worldwide, perpetual, and transferable license to use the images and other content for both commercial and non-commercial purposes".[2] While this license is central for Mapillary's commercial interests, the company makes an exception to its terms by allowing anyone to use information in the images to improve OSM. This is both a signal of support for the improvement of OSM, and a strategic practice related to Mapillary's reliance on the volunteer labor from the OSM community.

Mapillary's profitability stems primarily from the sale of business-to-business (B2B) services related to the images. The company's co-founder and many of its employees specialize in computer vision algorithms that extract information from street signs and other entities on the landscape. The resulting data are sold through monthly subscription plans. Additional services for purchase include the ability to make large numbers of image views, the establishment of private image repositories, and the rights to derive information from the images in support of for-profit activities. Mapillary also sells service level agreements (SLAs) guaranteeing availability of the data. Clients showcased on Mapillary's website include GIS consulting firms, local tourism boards, and public works authorities, although it is not clear which ones have

[2] See Mapillary Legal section (accessed Sept. 1, 2017) https://www.mapillary.com/legal.

purchased the services and which are operating under the free usage terms.

The use of crowdsourcing as an input to a commercial model presents unique challenges. One of these is the need to ensure high-volume, consistent quality, and widespread coverage in the user-submitted imagery. As a way to address this problem and encourage contributors, Mapillary uses gamification tactics, such as publicly listing the individuals and organizations who have contributed the most photos to the site. The results are displayed prominently by posting the statistics of top contributors in Mapillary's blog.

OpenStreetCam is very similar in concept to Mapillary; however, it was developed by a research team at Telenav, a Santa Clara, California-based company specializing in vehicle navigation technology and location based services. In January 2014, Telenav acquired Skobbler, a Berlin-based startup company focused on vehicle routing from OSM data. Later that year, Telenav implemented OSM in its popular Scout app that finds routes and points of interest, elevating the importance of OSM in Telenav's business model. Telenav employees are highly active in the OSM community through State of the Map conference participation, service on OSM boards, etc.

Telenav announced OpenStreetCam in a press release in September 2016 (Telenav 2016b), although a beta version of the project was demonstrated at the State of the Map US conference in July 2016. The platform was originally called OpenStreetView until Google expressed concerns that the name could be confused with its own Street View trademark (Van Exel 2016). The OpenStreetView name and web domain had itself been used by permission of John McKerrell who in 2009 built and open sourced an eponymous basic website for the crowdsourcing of street level images.[3]

As with Mapillary, contributors to OpenStreetCam install an app on a smartphone that takes photographs at regular intervals. Although this app can be used when walking or biking, the main focus of OpenStreetCam is in-vehicle data collection—indeed the project encourages the submission of on-board car diagnostic device data to accompany collected imagery. Contributors upload their images for everyone to see on the web. As was demonstrated at State of the Map, OpenStreetCam is working on computer vision algorithms that can extract information about street signs and other entities on the landscape from street level images.

This information then can be used by OSM contributors to supplement their map improvements. The tracks of geographic coordinates associated with the images are also likely valuable to Telenav for understanding directional restrictions, speed limits, intersection layouts, and other roadway features that can improve the accuracy of its navigation products. Such information is routinely collected by Google in its own Street View vehicles to improve Google Maps (Madrigal 2012), and in similar fashion Telenav data collection teams conduct driving missions and share the associated images into OpenStreetCam for public use. For example, Telenav has collected 12,000 km of OpenStreetMap coverage in Ecuador and 11,000 km in Mexico City, which its employees are using to enhance the OSM road network with details such as turn restrictions, speed limits, and signage (Gonzalez 2017).

Like Mapillary photos, OpenStreetCam images are licensed as CC BY-SA and remain the property of the contributor to remove when desired. Unlike Mapillary, Telenav does not sell any services related to the collected images. However the OpenStreetCam terms of use state that by using the service, contributors grant Telenav a license to use the content for commercial purposes, including sub-licensing it.[4]

OpenStreetCam also uses gamification as a prevalent feature of the user experience. Like Mapillary, this

[3] This original OpenStreetView garnered over 100,000 images and 2500 users (Alex Illisei and Van Exel 2016). The visualization mechanism was similar in nature to Panoramio allowing users to click individual images on a map, although McKerrell himself posted a demonstration of how sequential streetscape photos could be acquired. See https://vimeo.com/6771405 and the project wiki page on the OpenStreetMap site at http://wiki.openstreetmap.org/wiki/OpenStreetView (2009).

[4] "You hereby grant to Telenav a worldwide, royalty-free, non-exclusive, perpetual, irrevocable license to do any act that is restricted by copyright, database right or any related right over anything within the Content, whether in the original medium or any other. These rights explicitly include commercial use, and do not exclude any field of endeavor. These rights include, without limitation, the right to sub-license the Content through multiple tiers of sub-licensees and to sue for any copyright violation directly connected with Telenav's rights under these Terms of Use." (Telenav 2016a).

is used to encourage participation, as well as direct contributors to areas where coverage is needed. Contributors can choose to accrue points as they add more kilometers of imagery. Images obtained from previously uncollected locations multiply the points. Tallies are reported in leaderboards for the previous day, week, and month. OpenStreetCam users see a report of their points upon logging into the website.

The emergence of crowdsourced street-level imagery platforms, such as Mapillary and OpenStreetCam, both relies on and disrupts the community of crowdmappers that originally developed around OSM. By providing incentive of improving this non-profit collective project through street-level imagery, private firms such as Telenav and Mapillary leverage labor from the contributor community and incorporate it as an input into the creation of economic value. Drawing from this resource has important consequences both for the dynamics of the OSM crowdmapping community, and for the commercial prospects of these private firms.

However, the relationship between these commercial initiatives and the OSM collective project is complex, and transcends the use of unpaid mapping labor. Mapillary and OpenStreetCam both bring real benefits to OSM by expanding map coverage through street-level imagery, and doing so in terms that—while benefitting these firms commercially—are still more open than those provided by Google Street View. The provision of this kind of imagery to OSM also represents qualitative improvements, since it allows expansion of mapping by capturing features that would not be visible from overhead imagery. In the next section we explore the shifts resulting from the emergence of crowdsourced street-level imagery platforms by focusing on the tensions that arise between competition, contribution, and collaboration in the relationships between Mapillary, OpenStreetCam, and the OSM community.

Competition, contribution, and collaboration

Uploads made to street-level imagery platforms are more simplistic and homogenous in nature than OSM contributions because of the limited variety of entities that can be volunteered (i.e., just photos and coordinates). At the same time, collecting street-level imagery offers different challenges. The "armchair mapping" that is possible in OSM by tracing remotely sensed data is not an option when contributing to Mapillary or OpenStreetCam. Instead, contributors must have the ability, means, and will to physically visit the place being mapped and capture imagery in the process. Thus, given the physical and logistical challenges involved in acquiring street-level imagery, the gamification elements of these platforms give much greater importance to the number of kilometers mapped versus what exactly gets captured in the photographs.

Both Mapillary and OpenStreetCam are taking in millions of street level images from volunteer contributors. Although these two organizations use the images in different ways, they license them under very similar terms and provide a comparable service. Why, then, the two different platforms? The answer hearkens back to the for-profit nature of the two parent companies. Recognizing the value of street level images for extracting road sign content, lane information, vehicle tracks, and other landscape features for its navigation products, Telenav—OpenStreetCam's parent company—originally investigated entering into a contract to use Mapillary's data. Although the two companies collaborated for a time, Telenav ultimately balked at paying "hundreds of thousands of dollars in license fees" asked by Mapillary and decided to launch its own project, which would become OpenStreetCam (Illisei and Van Exel 2016). The company's most prevalent messaging, however, is that OpenStreetCam was developed to improve the quality of OSM and offer a street-level imagery solution with open sourced components.

The value that Mapillary and OpenStreetCam images bring to OSM is undoubtedly immense. For example, without extensive local knowledge of an area or detailed notes from an onsite visit, a mapper is limited to tracing those items that are available from overhead satellite imagery. The introduction of street-level imagery reveals an additional set of useful details, such as address numbers, storefronts, street signage, right-of-way restrictions, and bus stops. Barred from using Google Street View as a source due to copyright concerns, OSM contributors have latched on to Mapillary and OpenStreetCam as gold mines of information. Both parent companies have devoted extensive resources toward integrating smoothly into OSM editing tools so that contributors can view street level images while in the act of making

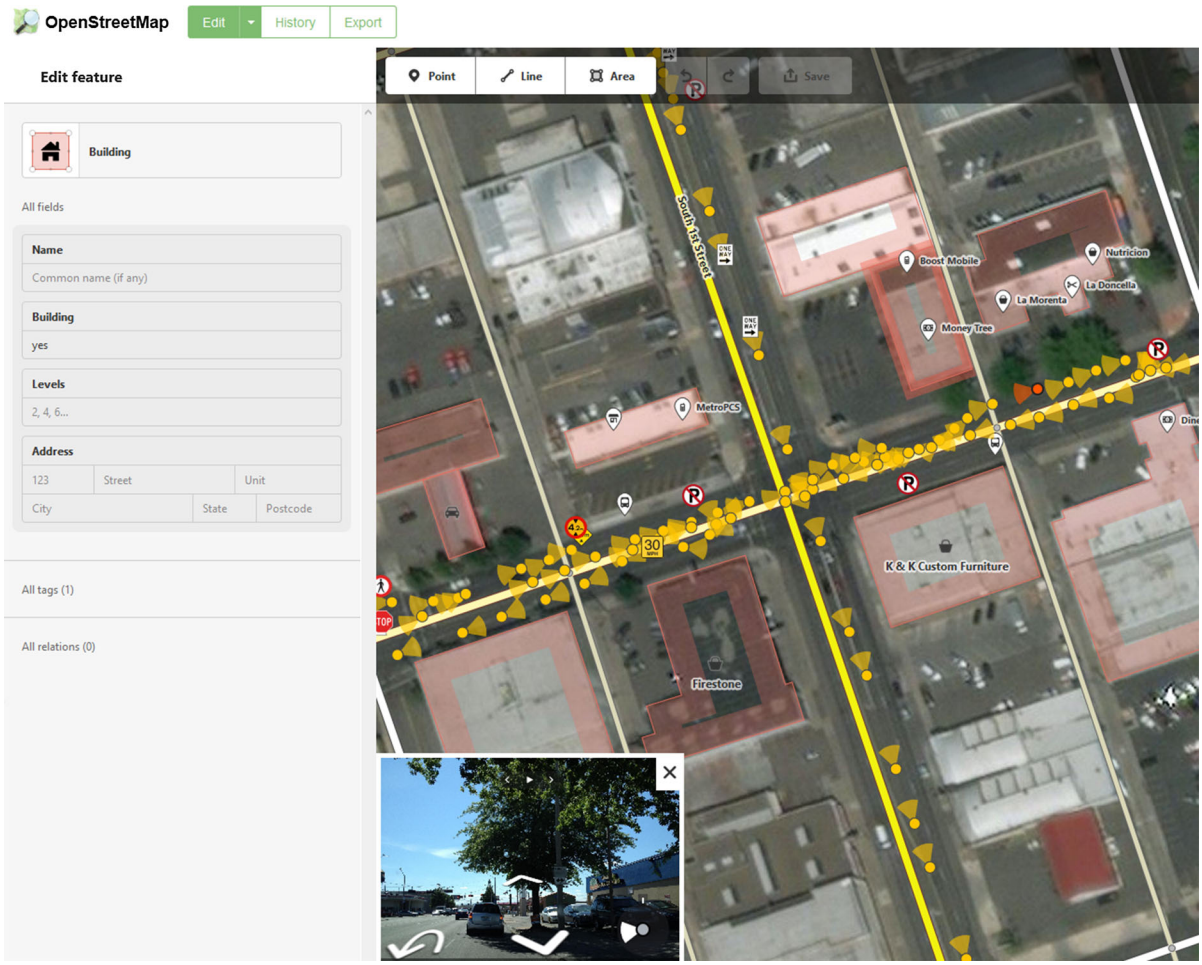

Fig. 1 Mapillary imagery (symbolized by yellow dots) integrated into an OSM editing program. (Color figure online)

changes to the map. For example, Fig. 1 shows an example of Mapillary imagery integrated into the iD editor for OSM. Figure 2 shows the details that can be added to a basic road network in OSM by scrutinizing this street-level imagery as opposed to solely using the overhead imagery.

The positive rhetoric from Mapillary and OpenStreetCam about openness and OSM enhancement is somewhat shaded by the necessary competition for labor occurring between the two. This competition will always be present because the two platforms do not draw from a limitless pool of labor, but from an existing, well-defined, community of contributors that has converged around OSM. Additionally, in order to contribute to either Mapillary or OpenStreetCam, contributors must offer, free of charge, resources that include time, electronic equipment, vehicles, fuel, and Internet bandwidth (Table 1). Without such contributions, the projects would cease to exist. While OpenStreetCam does not actively recruit contributors outside of the OSM community, Mapillary has a program advertised in their community page that specifically aims to recruit humanitarian workers and NGOs as Mapillary Community Partners.[5]

Online discussions by Mapillary and OpenStreetCam contributors reveal a somewhat restive user community, aware of its status as a coveted labor resource, while at the same time struggling to fully discern the motives of the projects and their terms of use. A would-be image contributor on the OpenStreetCam user forums sparked a long discussion with the questions: “So why should I, as a user of

[5] See https://www.mapillary.com/community.

OpenStreetMap with basic streets

Buildings traced from satellite imagery

Details added from crowdsourced street-level imagery

Fig. 2 A basic road network in OSM wherein a street has been enhanced with building traces from overhead imagery and further details from street-level imagery

Mapillary, switch [to OpenStreetCam]?…. Could you just cooperate to integrate the images you collect into both databases?" Responses revealed that contributors did not enjoy submitting imagery to two separate platforms, and that they did not fully understand the terms of use of the different projects. The thread eventually garnered animated comments from official representatives of both projects trying to clarify the purposes of the two platforms and the rights retained by contributors.[6]

The nascent body of literature around the ethics of crowsourced labor has largely focused on projects where the contributors receive some kind of monetary compensation, such as Amazon Mechanical Turk (Durward et al. 2016). In contrast, Mapillary and OpenStreetCam are closer to projects that Schmidt (2013) classifies as "volunteer crowd work", where contributors are motivated by the idea of contributing to a greater good and expect no pay for their labor. Yet, even these types of projects may present ethical dilemmas with intellectual property when participants encounter restrictions to using the products of their work (Kocsis and de Vreede 2016). In this sense, Mapillary and OpenStreetCam are more generous and transparent than "disguised" crowdsourcing mechanisms such as reCAPTCHA, where participants may never know or be able to access the text they have transcribed. Any contributor to one of these street-level imagery platforms can access their contributions at any time; yet access to the entire corpus of Mapillary or OpenStreetCam images is more complicated and may be restricted by terms of use. For example, Mapillary's terms and conditions specifically prohibit "mass downloads". Furthermore, these terms and conditions structure the creation and appropriation of value within each of these platforms in specific ways that correspond with the role and position occupied by their parent firms in the broader economy of the geoweb and geospatial data more generally.

In this context, the existence of dueling platforms for crowdsourced street-level imagery raises key questions about the relationship between contribution, competition, and collaboration. Given that a paywall restricted certain uses of the Mapillary imagery collection, it should be no surprise that a competing platform emerged. The entrance of OpenStreetCam

[6] See "Cooperate with Mapillary?/Difference to Mapillary?" thread on Github (accessed Sept. 25, 2017): https://github.com/openstreetcam/openstreetview.org/issues/60.

Table 1 Resources expended by volunteer contributors to crowdsourced street-level imagery platforms

Resources expended when collecting street level imagery	
Resource type	Description or example
Time and labor	Navigating streets and paths, quality-checking photos, uploading photos, and optionally post-processing photos (such as adding more blurs to faces or other features)
Camera	Smartphones, tablets, and action cameras
Vehicle	Motor vehicle or bicycle
Vehicle upkeep	Registration, licensing, insurance, and regular maintenance required to operate a vehicle
Energy resources	Motor vehicle fuel, as well as batteries, electricity, and chargers for the camera
Supporting technical equipment	Mounting devices for the camera, on-board diagnostic devices for vehicle metrics, windshield cleaner, and anti-glare material (such as black felt for a vehicle dashboard)
Internet resources	Wi fi (or cellular data) connections and bandwidth to upload imagery reaching gigabytes in size

potentially fragments the volunteer labor force, and pushes contributors to choose which platform(s) they will support. Given that technical and/or legal obstacles prevent the entire body of images from being downloaded or mirrored from either project, it is possible that other organizations could launch similar projects to collect street level image sets, further subdividing the community of contributors. This also gives rise to the concern that one or both projects could in theory be terminated (or bought out) without a way for the community to preserve or build upon the entire set of collected images.

This competitive environment makes it difficult for contributors to collaborate about maximizing coverage and avoiding duplication, a mainstay of effort in OSM communities. Indeed, Mapillary and OpenStreetCam are tacitly encouraging duplication because both platforms desire imagery on all streets. The competing platforms may attempt to overcome the collaboration deficit through elements of gamification, such as multiplying points for previously unexplored roads (Fig. 3). The irony of this approach is that, through a carefully designed system of incentives, the quest for individual recognition and prominence is reinforced as the motivating element for collaborators within these platforms, rather than the desire to work as part of a team toward a common goal.

All the while, there is little to impede the appearance of a third or fourth platform collecting the same type of imagery. Would a cycle develop of people collecting the most common geographies on new platforms, without spending enough time on any one platform to achieve the detailed level of coverage needed to compete with private sector data collection such as Google's? Or would the arrival of new platforms simply bring in new contributors who could eventually fill each platform with imagery?

These discussions have caused contemplation about what a single truly open platform for crowdsourced street level images would look like. Given what we have observed from the engineering of Mapillary, OpenStreetCam, and Google Street View, the common elements of a street-level imagery platform include:

- Image collection software (likely a mobile app) leveraging satellite-based positioning, orientation information, and the device's camera.
- An API and/or user interface for uploading images
- Mechanisms for post-processing the imagery to remove sensitive information such as faces and license plates.
- Hardware for storing the images and an optional delivery network for rapid access
- A web interface for viewing the images and an API for retrieving them programmatically.
- Optional plugins for integration with OSM editing tools

An obvious question is that if such a platform were to be developed and operated by a non-profit institution, perhaps similar in nature to the OpenStreetMap Foundation, where would the necessary resources be procured to develop and maintain all of the above-listed components? Would the amount of capital required necessitate the involvement of the private (or public) sector? Certainly storage space would need to

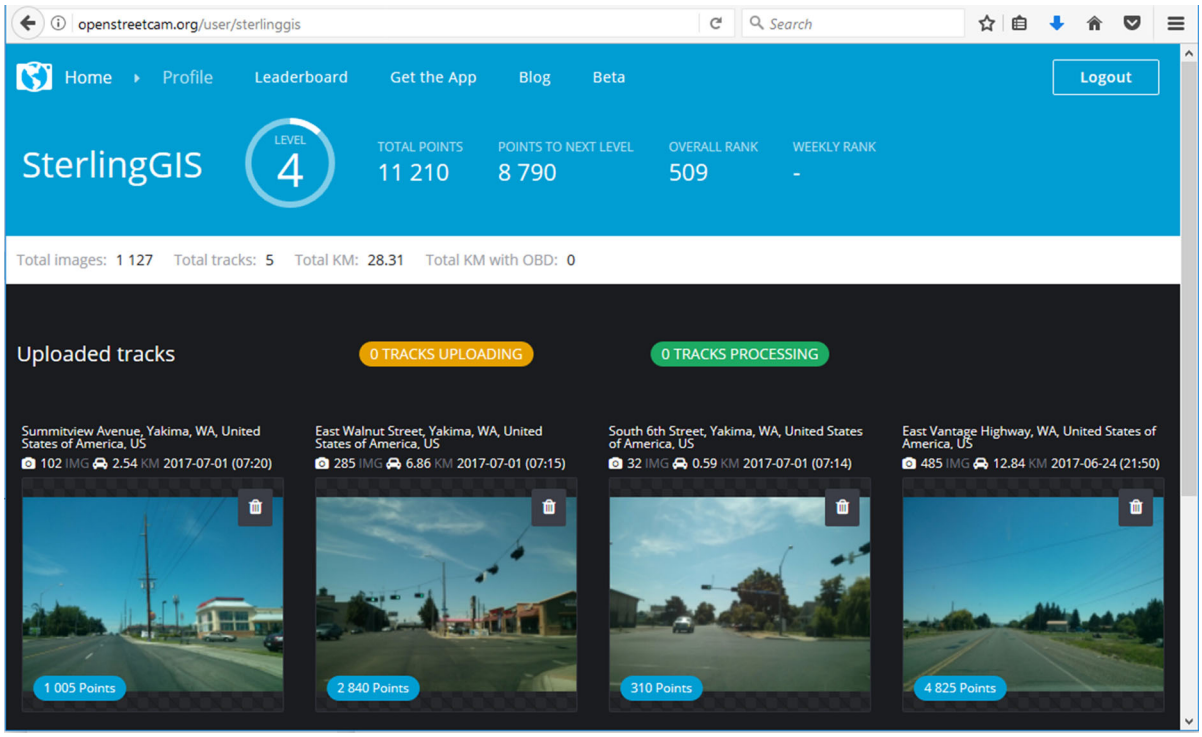

Fig. 3 Gamification elements in an OpenStreetCam user profile page. Similar elements such as leaderboards are also present in Mapillary

be apportioned, but human labor would also be needed to develop the software layer. McKarrell's original OpenStreetView was probably the most advanced implementation of a street-level imagery platform without any tie to a commercial interest (that we could determine), but it was Telenav's investment in hardware and software development that scaled the project to a much larger audience. At the same time, Telenav's decision to open source the OpenStreetCam apps and website code (Illisei and Van Exel 2016) may have lowered the barrier to the implementation of imagery platforms by others in the future.

Beyond these topics lies the broader question of to what degree any crowdsourced platform for street level images is even sustainable and whether it can ever compete with commercial alternatives. Google has achieved blanket Street View coverage in many cities and countries due to the organized nature of the project, which it funds, plans, and executes itself. Google Street View also implements regular update schedules for highly-visited areas, laser range data for 3-D modeling of buildings, and 360-degree seamless panoramas (Anguelov et al. 2010; Vincent 2007), making crowdsourced alternatives look rudimentary in comparison.

Furthermore, the coverage maps on the Mapillary and OpenStreetCam web sites show vast regions of missing data throughout the United States and elsewhere. We know that OSM has developed unevenly across world regions (Neis et al. 2013), as well as more nuanced geographies of socioeconomic status (Haklay 2010), rurality (Camboim et al. 2015), and gender (Stephens 2013). We speculate that spatial biases in street-level imagery collection would be even more acute than in OSM, due to the requirement of physically visiting a location (whereas OSM can be mapped remotely from tracing satellite imagery). Spatial variations in street-level imagery coverage would be a useful area for future research, although it is unclear whether sufficient data could be retrieved from either the Mapillary or OpenStreetCam platforms under the current terms of use to conduct any kind of robust analysis. Another point of study is the degree to which these platforms' parent companies will rely on their own data collection teams to supplement coverage not offered by the crowd.

Beyond the questions of coverage and resources necessary to implement sustainable crowdsourced street-level imagery platforms (both commercial and non-commercial), there is the core issue of how they structure the creation and allocation of economic value. Specifically, it is necessary to identify and analyze the mechanisms by which the two existing platforms in this realm, Mapillary and OpenStreetCam, leverage unpaid labor from an existing contributor community, incentivize contributors to physically acquire new imagery, retain rights of use to said imagery, and incorporate it into business processes that eventually contribute to profits—which their parent firms can appropriate. In the following section, we use a property regimes approach to explore these questions and identify the roles of various actors in the process of value creation, the rules that govern their interactions, and the allocation of rights over the content and profit of these platforms.

The property regimes of crowdsourced street-level imagery[7]

While the concept of property has been long influenced by monolithic understandings that equate it with a "sole and despotic dominion" (Blackstone 1893), legal scholars have acknowledged in recent decades (Heller 2000; Hsu 2002) that, in the real world, property has seldom conformed to the binary 'all-or-nothing' nature implied by this conception. In this context, the idea that there are stable and predetermined categories of property has become increasingly contested. We argue that the conceptual schema put forth by Schlager and Ostrom (1992) to analyze 'property-rights regimes' represents a breakthrough in the analytical toolkit for understanding the shifting ways in which property is organized and, crucially, the means and relationships through which this is carried out. Rather than a monolithic right, this schema relies on a conception of property as a 'bundle of rights' which can be differentially assigned to various actors under a particular set of rules. This allows for a flexible, finely-grained analysis able to capture the multiple possible configurations in the creation, distribution, and appropriation of value through the exercise of property over particular resources.

In this article we prefer the term 'property regimes' to Schlager and Ostrom's original term property-*rights* regimes. This is because, in addition to analyzing the rules and rights involved in the construction of this schema, we also develop an examination of the technical means and social practices by which this is made possible. Through this wider lens we are then able to observe a fuller picture of how Mapillary and OpenStreetCam implement particular sets of terms and conditions in order to leverage the dynamics of crowdmapping for the creation and appropriation of economic value, that is both defined by their orientation as commercial ventures, and their interdependence with a collective not-for profit collaborative project such as OSM.

The property regimes framework is structured by different kinds of rights over a particular resource, which are assigned to specific roles. Rights are defined by three different levels of rules: operational, collective action, and constitutional. Operational rules are those that define how actors can exercise rights over a particular good. Collective action rules, which are one level higher, establish operational rules by allowing some actors to define the rights of other actors over a good. Collective action rules, in turn, are defined at the constitutional level. This system of rules generates two rights at the operational level (access and withdrawal), and three rights at the collective action level (management, exclusion, and alienation). These rights can, in turn, be assigned to four different roles: authorized user, claimant, proprietor, and owner. While the authorized user has the least rights over a good, the owner has the most, and is closest to the traditional, absolutist conception of property. The allocation of rights to roles that structures a property regime is represented in Table 2.

OpenStreetCam

Collaboration and profit act as joint drivers of OpenStreetCam's strategy, echoing numerous other crowdsourcing ventures that derive economic value by

[7] The terms and conditions for Mapillary and OpenStreetCam consulted for this research are available online in the URLs indicated throughout the footnotes in this section. However, the content of these documents might be modified with little or no public notice. To address this, the authors have saved versions of Mapillary's Legal and Licensing Section and OpenStreetCam's Terms and Conditions of Use (last accessed on Feb. 16, 2018), and can make these available to readers upon request.

Table 2 Rights and roles in a property(-rights) regime. With information from Schlager and Ostrom (1992)

	Roles			
	Owner	Proprietor	Claimant	Authorized user
Rights				
Operational level				
Access and withdrawal	X	X	X	X
Collective action level				
Management	X	X	X	
Exclusion	X	X		
Alienation	X			

leveraging the rhetoric and practice of amateur collaboration (Brabham 2012). Despite key divergences, collaboration and profit are strategically complementary for OpenStreetCam's operations. By appealing to the crowd's investment in OSM, and the desire to improve that collective not-for-profit project, Telenav—a private corporation—can acquire, at a negligible cost, a wealth of crowdsourced imagery and vehicle tracks that it can use to improve its navigation products. This combination of collaboration and profit brings up the question of how economic value is created and distributed between OSM, the user/contributor community, and Telenav.

This creation and distribution of value through OpenStreetCam is enabled by a property regime that is explicitly articulated for this purpose. This is done through the combination of rules regulating the exchange of narrowly defined rights, and technical systems deployed to implement and monitor those exchanges. In the case of OpenStreetCam, the aim of Telenav (as stated in the Terms and Conditions of Use) is to create the "biggest possible repository of street level photography imagery".[8] To this end, Telenav has open sourced OpenStreetCam under a "sLGPL Licence" and licensed the imagery under the Creative Commons Attribution-ShareAlike (CC-BY-SA) 4.0 International license. This dual licensing distinguishes the end product as such (OSC) from its constitutive images contributed by crowdmappers. From a political economic standpoint, these licensing agreements structure the conditions for creating and distributing economic value through OpenStreetCam. It is therefore essential to unpack such agreements and their ensuing relations in order to answer questions such as who 'owns', or profits from, OpenStreetCam (and the images therein).

Telenav does not claim ownership of the content submitted by OpenStreetCam users. However, users' acceptance of the Terms and Conditions within OpenStreetCam, grants the parent firm "worldwide, royalty-free, non-exclusive, perpetual, irrevocable" rights to use and sub-license users' images for any purpose, including commercial uses. On the other hand, Telenav grants anyone with access to OpenStreetCam the rights to "copy, distribute, transmit and adapt data on OpenStreetCam", as long as there is compliance with the "applicable open source license" and credit is given to Telenav and the OpenStreetCam contributors. Yet, while contributors receive credit for their content, by submitting it to OpenStreetCam, they also agree not to revoke any rights over such content from Telenav.

In tension with the idea of collaboration, this waiver represents an asymmetric relationship where contributors' content is permanently bound by the initial decision to participate in OpenStreetCam. This asymmetry is further reinforced by the fact that contributors may not "resell, assign, or transfer any of [their] rights hereunder" under penalty of termination of the Agreement, while Telenav, on the other hand, "may assign this Agreement to any affiliate at any time without notice." These rights exchanges between contributors and Telenav are governed by broader legal frameworks, labeled "applicable local laws and copyright conventions". However, while in this case, the legal framework is the Laws of the State of California, per the Terms and Conditions, any claim or

[8] Citations from OpenStreetCam's Terms and Conditions of Use included in this section are taken from the Terms and Conditions of Use web page (Effective as of August 1, 2016, accessed August 8, 2017): https://www.openstreetcam.org/terms/.

dispute between the contributors and Telenav will be settled through independent arbitration. The conditions contained in the agreement that contributors enter with Telenav when they participate in OpenStreetCam, are thus geared towards ensuring that the company can secure access to the imagery and any forms of value creation that use it as an input. How this value is created and distributed is a process that can be examined through an analysis of the property regime articulated by the conditions outlined above.

In OpenStreetCam's property regime, economic value is created by the acquisition of street-level imagery and vehicle tracks from contributors, and the extraction of valuable data from this imagery through machine-learning algorithms, which is then used for the improvement of Telenav's core business products: vehicle navigation technology and location based services. This process takes place through a series of exchanges that involve the differential allocation of rights over the images and the value derived from them.

The Terms and Conditions of OpenStreetCam explicitly recognize the contributors of street-level imagery as the owners of the content. However, by agreeing to such terms, these owners give up two core rights that constitute ownership over their contributions: alienation and exclusion rights. In this case, the duplicability of the digital objects makes it more difficult to retain exclusive control over the images, since submitting content to OpenStreetCam necessarily implies making a copy that is hosted by the platform and licensed to Telenav in perpetuity. This is reinforced by the fact that Telenav's terms ensure that the firm retains a broad set of rights over the imagery even after contributors terminate, deactivate, or archive their accounts. Thus, although they are credited as owners of their data, contributors can only exercise rights to access and withdrawal, and management of data. This means that, under the property regimes schema presented here, contributors are only owners of their data in nominal terms, since, in practice, the rights they retain correspond more closely to the role of claimant.

The rights acquired and exercised by Telenav allow the firm to access and withdraw imagery, manage it within the OpenStreetCam platform, and exclude users by terminating their access to the platform. While Telenav does not have the right to sell the imagery, since it is technically owned by the contributors, it retains the right to sub-license it for any use—including commercial uses. Therefore, while this does not constitute the right to alienate, it achieves one of its core objectives, which is to license the management rights to other parties. By obtaining a perpetual license to the imagery, and retaining control of it within the OpenStreetCam platform, Telenav has a broad set of rights over the imagery. This set of rights is nominally checked by the contributors' ownership over the imagery. However, in practice, the Terms and Conditions of OpenStreetCam prevent contributors from checking any of the rights transferred to Telenav. On the other hand, the duplicability of digital images comes into play in this relationship, since it allows contributors to retain control over their own copies of the imagery.

OpenStreetCam serves as the interface that controls and allows access, withdrawal, and management of the imagery repository submitted by contributors (Table 3). By exercising the right of management, through OpenStreetCam, the parent firm Telenav takes on the role of claimant in this property regime—even though, by retaining broad image licensing rights, in practice its role is closer to that of the owner. Lastly, authorized users are those who can view and download street-view imagery from OpenStreetCam. Barring any deliberate exclusion from Telenav, or any external restrictions (such as technical limitations, or censorship), members of the general public take on the role of authorized users of the content of OpenStreetCam.

Mapillary

Like in the case of OSM, and in a majority of digital products and services, the Terms and Conditions of Use[9] establish the rights assigned to different parties in the Mapillary property regime. In this case, the key object over which rights are apportioned is the imagery submitted by contributors to the platform. Specifically, the property regime in this case is set up for the commercialization of Mapillary's crowdsourced imagery and extracted data, rather than as an input for secondary products, as done by Telenav through OpenStreetCam.

[9] The Terms and Conditions of Use citations in this section are taken from Mapillary's Terms and Conditions of Use web page (accessed Aug 9, 2017), unless otherwise noted. See: https://www.mapillary.com/terms.

Table 3 OpenStreetCam property regime

Role	Access and Withdrawal	Management	Exclusion	Alienation	Actor(s)	Type of exchange
Owner	X	X	X	X	Contributors	Contributors submit imagery to Telenav through OSC; free of charge, points awarded
Proprietor	X	X	X		Telenav	Telenav extracts information from imagery, and uses it to improve OSM (free of charge) as well as their own navigation tools, which they sell to customers
Claimant	X	X			OpenStreetCam	Telenav, through OSC awards points to contributors in exchange for imagery
Authorized user	X				General public	General public can access and download OSC imagery free of charge

According to Mapillary's Terms, each user retains "all associated intellectual property rights" over the content they upload. However, by contributing to Mapillary, users grant the company a "worldwide, perpetual, and transferable license to use the images and other content for both commercial and non-commercial purposes".[10] As such, contributors are identified as owners in the Mapillary property regime, although the same practical restrictions apply as those described in the OpenStreetCam case.

Since improving OSM is important for Mapillary's messaging and the company's relations with the OSM community, this orientation is reflected in the licenses that govern the use of imagery. In order to be compatible with OSM's contributor terms, "Mapillary grants a special license for OSM. Images and data available on Mapillary may be used freely to edit OSM and any content derived may be submitted under the OpenStreetMap Foundation contributor terms to OSM".[11]

Under Mapillary's pricing plan, authorized users can make up to 50,000 views free of charge. This does not allow non-image-data requests, and is governed by a Creative Commons Attribution-ShareAlike (CC-BY-SA) license. This license allows users to share and adapt images as long as they give appropriate credit, provide a link to the license, and disclose any changes. Furthermore, the CC-BY-SA license also allows them to distribute the content under the same license as the original, without imposing any additional restrictions (Creative Commons, n.d.). However, this license only applies to Mapillary's free pricing plan, which does not cover commercial uses of the imagery on the platform.

While anyone can access Mapillary under the free plan, or pay accordingly for commercial plans, developers are considered separately. Developers play a different role through a specific use case of Mapillary, which is characterized by using the platform's tools (such as API, tiles, and vectors) to build separate web services. A separate Developer Use Policy governs most cases of developer use. According to this document, developers must be registered with Mapillary, which allows them to use the platform to make up to 50,000 views of street-level imagery free of charge. After this limit, developers should purchase a commercial plan, which is governed under the terms of the Commercial Use Supplement. By purchasing a plan under these conditions, developers, like other paying customers, would then be granted by Mapillary "a world-wide, perpetual, non-transferable license to the images and to any data [they] derive from the images".[12]

The principal distinction between use of Mapillary under the general Terms and Conditions, the Developer Use Policy, and Commercial Use is that the latter represents an exchange where the user, who is now

[10] See Mapillary Legal and Licensing (accessed Sep. 21, 2017): https://www.mapillary.com/legal.

[11] See Mapillary Legal and Licensing (accessed Sep. 21, 2017): https://www.mapillary.com/legal.

[12] The Commercial Terms citations in this section are taken from Mapillary's Commercial Use Supplement (accessed Sep. 21, 2017). See: https://www.mapillary.com/commercialterms.

referred to as customer, explicitly intends to use Mapillary for profit, and does so by paying for it as a service. As opposed to the free plan, where the use of images is governed by a CC-BY-SA license, commercial uses fall under a separate commercial license. This allows internal use of imagery by the clients, but forbids reselling.

The pricing plans established in the Commercial Use Supplement are classified according to the volume of views, availability of data by request, and the types of licenses. In exchange, Mapillary provides access to the imagery for commercial uses, guaranteeing "uptime equal to or better than 99.8% per month",[13] and offering service credits to customers if this percentage is not met. In addition to the monetary exchange established by the pricing plan, an informational exchange takes place under the Commercial Terms, which allow Mapillary to collect "data (including meta-data, analytical, diagnostic and technical data, and usage statistics) concerning or arising from Customer's and all Authorized Users' use of the Mapillary Solution".[14]

Mapillary is a site governed under Swedish law, where Mapillary AB Corporation is based. While the Swedish legal framework governs the site itself, users agree to resolve any disputes with the platform through arbitration—as in the case with OpenStreetCam, users agree to resolve any disputes with the platform through arbitration. Any disputes arising in this context are settled before the International Court of Arbitration, in accordance with the Rules of Arbitration of the International Chamber of Commerce (ICC). While these can be conducted online or over the phone, if in-person appearance is required, this will take place in Copenhagen, Denmark. This legal arrangement makes Mapillary AB Corporation the proprietor of the imagery submitted by the users, since it retains rights of access and withdrawal, management, and exclusion—while the right of alienation is nominally reserved for contributors. While its parent corporation also has management rights, it is the Mapillary site that takes on the role of claimant, and exercises management of the imagery through technical controls such as a user registration system and the monitoring and limiting of the number of image views.

The legal framework summarized above regulates and oversees the exchanges of rights that form the core of the Mapillary property regime, which is oriented towards the creation of economic value through crowdsourced imagery. Mapillary's business model is primarily reliant on selling imagery-related business-to-business (B2B) services. A main component of these is the extraction of information from the landscape through computer vision algorithms. The various types of pricing plans, the licensing for commercial uses, and service level agreements complement this model. A summary of the rights, roles, and rules structuring the Mapillary property regime can be found in Table 4.

Conclusion

This article has explored the emergence of crowdsourced street-level imagery platforms Mapillary and OpenStreetCam. The use of crowdmapping in the collection of street-level imagery represents significant disruptions both in the street-level imagery ecosystem, and in the crowdmapping community. Street-level imagery is currently dominated by Google Street View, a corporate actor with a well-funded and organized proprietary imagery collection operation. Crowdmapping, and specifically, the collaborative project OSM, are characterized by large numbers of volunteer mappers and a generalized sense of collaboration towards a common goal. The use of this platform for commercial purposes is not an unprecedented phenomenon. However, the incorporation of crowdsourcing as an input for street-level imagery by Mapillary and OpenStreetCam introduces new dynamics of competition for the free labor of crowdmappers, and relies on the collaborative ethos surrounding the OSM collective project.

We note that this nature of competition can happen even with software products that are not funded by for-profit companies (for example, free and open source software projects that have been "forked" due to competing developer visions). However, in this case, it is worth pointing out the specific nature of the competition, characterized by leveraging non-profit

[13] The Commercial Terms citations in this section are taken from Mapillary's Commercial Use Supplement (accessed Sep. 21, 2017). See: https://www.mapillary.com/commercialterms.

[14] The Commercial Terms citations in this section are taken from Mapillary's Commercial Use Supplement (accessed Sep. 21, 2017). See: https://www.mapillary.com/commercialterms.

Table 4 Mapillary property regime

Role	Access and withdrawal	Management	Exclusion	Alienation	Actor(s)	Type of exchange
Owner	X	X	X	X	Contributors	Contributors submit images (to which they must own the rights) to the Mapillary application, granting Mapillary AB a perpetual, nonexclusive, transferrable, irrevocable, royalty-free, worldwide license over them In exchange, contributors are awarded points according to the coverage they submit to the application. Contributors retain the rights over their images, although they cannot revoke the license from Mapillary
Proprietor	X	X	X		Mapillary AB (Corporation)	Mapillary AB receives images from individual contributors, which it uses to build the Mapillary application. The company is able to enact rights of access, withdrawal, and exclusion to images based on its general Terms, Developer Policy, and Commercial Use Terms. These terms have to be accepted in order to use the Mapillary application
Claimant	X	X			Mapillary Solution (Application)	The Mapillary application manages the access and withdrawal of images by authorized users by two main means: (1) through a registration system that manages different types of users, and (2) by monitoring and limiting the number of image views
Authorized User	X				General public/Developers under Developer Usage Policy/Customers under Commercial Terms/OSM under special license	The general public can access, download, share, and edit images free of charge. Some editing features require creating an account Developer use requires registration and is free up to 50,000 views For use cases requiring higher volume, and for commercial purposes, users need to register as customers and purchase a pricing plan under the Commercial Terms, which has to be agreed in a signed writing Mapillary allows its images to be used freely for the improvement of OSM under a special license, under the OSM contributor terms

collaboration towards a for-profit enterprise, and a built-in system of incentives—such as gamification elements found in Mapillary and OpenStreetCam. This arrangement can have important implications for the emergence and development of free and open alternatives to large scale corporate platforms such as Google Street View.

In order to understand the new dynamics of competition, cooperation, and collaboration introduced by the use of crowdsourced street-level imagery for commercial purposes, we have deployed a property regimes framework. Through this framework we analyzed the rules governing the creation and allocation of economic value through these two platforms. As we showed, these rules are generated specifically for the type of economic activity at the core of each corporation's business model and the monetary and informational exchanges that make it possible. Such exchanges, in turn, are enabled by the differential allocation of narrowly defined rights over the imagery that constitutes the core of these platforms. In conducting this analysis, we argue that deeper understandings of the economic and technological transformations sweeping through the geoweb must take into account an integrated view of the rules, rights, and roles structured through the specific property regimes that structure the increasingly variegated creation and allocation of economic value through geospatial data.

The tensions between competition, collaboration, and cooperation that color the interactions between Mapillary, OpenStreetCam, and the OSM community, are indicative of deeper dynamics structuring the geoweb in the context of digital capitalism. While large-scale open source collaborative online projects such as OSM, or even Wikipedia, have managed to survive and expand, they coexist with a growing constellation of goods and services whose subsistence relies on profit. The Mapillary and OpenStreetCam cases show how open source and profit can be combined as a strategy to capture an existing labor base, and simultaneously improve open source projects, such as OSM. However, it is not clear that this strategy is viable for a large number of actors (given the potential for cannibalizing the labor base), or that it can continue expanding without damaging the growth and stability of the volunteer community on which it relies (and which is, for the most part, not motivated by profit). Thus, as shown by our property regimes analysis above, in order to understand new developments in the geoweb, and how they integrate into broader economic dynamics, it is important to examine the exchanges and interactions that structure the production and circulation of value, both within and between specific applications and sets of actors, such as Mapillary, OpenStreetCam, and the OSM community.

Compliance with ethical standards

Conflict of interest The authors report no potential conflicts of interest related to this research.

Human and animal rights No human or animal subjects were involved in the course of conducting this research.

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